RESEARCH DEPARTMENT

SOME EXPERIMENTS ON THE CALIBRATION OF VELOCITY MICROPHONES AT LOW AUDIO FREQUENCIES BY MOTIONAL IMPEDANCE MEASUREMENTS (SECOND REPORT)

Report No. M.009/2
Serial No. 1952/2

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CONFIDENTIAL

Research Department January 1952

REPORT NO. M.009/2

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SOME EXPERIMENTS ON THE CALIBRATION OF VELOCITY MICROPHONES AT LOW AUDIO FREQUENCIES BY MOTIONAL IMPEDANCE MEASUREMENTS

(SECOND REPORT)

Fig. Nos. M.009/2.1 to M.009/2.5

SUMMARY

Experiments on the low frequency calibration of ribbon type velocity microphones by electrical impedance measurements have been extended to diaphragm type microphones. One of these microphones has been calibrated by this method as a standard of frequency response in the range 40 c/s to 200 c/s and the calibration confirmed by free-air measurements.

The technique of calibrating ribbon microphones, described in Report M.009, has been improved and is now applicable to production testing.

INTRODUCTION

Report M.009 described an experimental technique for determining the frequency response of a velocity ribbon microphone up to about 1000 c/s by measurement of its motional impedance. It was noted, however, that ribbon microphones are not suitable for primary standards since the requirements of smooth response and high mechanical stability are to some extent incompatible.

The present report describes further work carried out on motional impedance calibration. This work has been divided into two parts. The first of these concerns the establishment of a diaphragm type primary standard on the lines indicated in paragraph 7 (c) of Report M.009, while the second deals with modifications made to the technique of calibrating ribbon microphones.

I CONSTRUCTION AND CALIBRATION OF DIAPHRAGM TYPE STANDARD MICROPHONE

General

The basic requirements of a diaphragm type microphone for motional impedance calibration are (a) that the diaphragm and coil should move as a whole throughout the working frequency range, and (b) that effective clamping of the coil should be practicable.

It is further desirable that the dimensions of the microphone should be small compared with a wavelength at the highest frequency of interest. However, as pointed out in Report M.009, this is not an essential requirement since the effect of departures from the ideal condition are a function of the geometry of the system and can be ascertained once for all.

To minimise the effect on the frequency response of small changes in the mechanical constants, it is preferable that the resonance frequency of the movement should lie well outside the working frequency range, i.e. that the system should be either mass-controlled or stiffness-controlled. It has not so far been possible to produce a mechanically stable mass-controlled system to meet the other requirements referred to, and for the present purpose it was therefore necessary to use a stiffness-controlled system.

A stiffness-controlled velocity microphone of the electromagnetic type can be shown to have a frequency characteristic rising by 12 db per octave and the signal/noise ratio from such a microphone at low frequencies is likely to be poor. To obtain the maximum sensitivity, the stiffness of the system should be kept as low as possible consistent with the requirement that the resonance frequency should fall outside the working range, in this case, above.

Many of these requirements could be met by a small cone loudspeaker unit of conventional type were it not for the relatively poor mechanical stability of the materials commonly used in the construction of the cone and suspension. Preliminary experiments were therefore carried out with a S.T. & C. 4017 moving coil microphone, which has a metal

diaphragm, the unit being modified to allow sound to reach both sides. The sensitivity was, however, very low and it was difficult to clamp the movement effectively without risk of damaging the moving coil. However, at this stage, there appeared on the market a small metal diaphragm loudspeaker unit which showed more promise. The remainder of the investigation was carried out with units of this type.

Description

This loudspeaker unit, Vitavox type 1084, is shown in Fig. 1. Being designed for naval use, it is exceptionally robust and unaffected by moisture. The light alloy diaphragm is $2\frac{1}{2}$ ins. in diameter and 3/8 ins. deep, and is corrugated at the circumference to give a higher compliance to axial movement. The only non-metallic moving part of the loudspeaker is the driving coil former, which is of paper treated with cellulose lacquer. There is no centring spider, the stiffness of the diaphragm and surround rendering this unnecessary. The diaphragm is protected by perforated guards at front and back. The nominal impedance of the unit is 3 ohms.

The fundamental resonance of this loudspeaker occurs at 750 c/s; the diaphragm can therefore be expected to move as a whole up to this frequency at least. If the diffraction round the unit is assumed to be the same as for a disk of the same diameter, the force exerted on the diaphragm by sound can be shown to be accurately proportional to frequency (within $\pm$ 1%) up to 750 c/s.

Experimental Procedure

The circuit used for calibration is shown in Fig. 2 in which the component numbering corresponds with that in the circuit of Fig. 1 in the first report. It was thought that with the higher impedance of the moving coil the effect of stray inductances would be less serious than in the case of a microphone ribbon and the dummy load Z2 of the original circuit has been replaced by a resistance R9. To obtain the best possible signal/noise ratio at low frequencies, condensor C1 originally connected in series with the input to the bridge is omitted. The driving force applied to the loudspeaker is now constant instead of being proportional to frequency; this fact is taken into account in arriving at the acoustic response.

The experimental procedure was similar to that described in the first report. Fortunately the element of the loud-speaker, unlike that of a ribbon microphone, behaves substantially as a system with lumped constants in the frequency range of interest; the response curve is therefore smooth and requires relatively few experimental points to define it.

Method of Clamping

Some difficulty was experienced in designing an effective, yet simple, means of clamping the moving coil during the adjustment of the static impedance balance. Such a clamp must permit not more than, say, 1% of the free movement and must be quickly and easily released. In addition it must not affect the acoustic properties of the microphone in the "free" position. Preliminary tests showed that to be fully effective the clamp must be applied to the driving point of the system, i.e. to the coil itself, and the arrangement shown in Fig. 3 was therefore devised.

Calibration of First Model

The first attempts at calibration were made with the microphone unmodified save for the addition of the clamping device.

The motional impedance of the system was found to be too low to be measured with the required accuracy. The chief sources of error were residual movement of the coil when clamped and the effect of temperature fluctuations on the resistance of the coil. More effective clamping could only be obtained by increasing the pressure on the coil to the point where the resulting deformation caused a small but troublesome change in the electrical resistance. In addition, to obtain an accuracy of $\pm$ 0.1 db in the calibration at the lower end of the frequency range it would have been necessary to balance out the static impedance of the coil to an accuracy of two parts in 10^5. It was not practicable to keep the temperature variation small enough to allow this accuracy to be obtained.

Modification to Surround

The difficulties associated with clamping and with temperature variations can both be decreased by reducing the mechanical impedance of the diaphragm, thus increasing the efficiency and hence the motional impedance. The fixed errors, due to the ineffectiveness of the clamping and to variations in temperature of the coil, then become a smaller proportion of the increased motional impedance. The stiffness of the diaphragm suspension was therefore reduced by cutting away most of the surround, leaving only four strips each about 1/8 in. wide. This reduced the fundamental resonance frequency to 360 c/s; the increase in efficiency was thus obtained at the cost of a restricted upper frequency range. With this modification, the clamping arrangement shown in Figs. 1 and 3 was found to be adequate, the movement of the coil at all frequencies of interest being reduced to less than 0.5% of its "free" value. The effects of temperature variations were no longer serious, but as an extra precaution, steps were taken to avoid large changes in ambient temperature during the measurements.

Results of Calibration

The plane wave frequency response of the microphone, as determined by the motional impedance measurement, is shown in Fig. 4. Below 200 c/s, the slope of the response curve approximates to 12 db/octave which would be obtained from a purely stiffness-controlled system. The slight rise in response below 65 c/s indicates that the compliance of the suspension is not quite constant, presumably because the effective length of the suspension strips is reduced with increasing frequency as the effect of the mass of the strips becomes appreciable. To obtain a more open scale, it is convenient to use a line having a positive slope of 12 db/octave as datum. This has been done in Fig. 5(a) for the frequency range up to 250 c/s.

Free-Air Tests

The absolute sensitivity of the microphone was determined by outdoor measurements between 40 c/s to 250 c/s. The results are shown in Fig. 5(b), a slope of 12 db/octave being

again used as a datum line. The notional impedance measurement does not give the absolute sensitivity of the microphone and the vertical scales for curves 5(a) and 5(b) are therefore lined up arbitrarily. The shape of those two curves shows good agreement.

The useful frequency range of this microphone is about 40 c/s to 200 c/s, the lower limit being set by the falling sensitivity, and the upper limit by the rapid rise in response as the resonance frequency is approached. This range, though only about 2 1/4 octaves, covers that frequency band in which a velocity standard is most necessary. At 40 c/s, the open-circuit sensitivity measured across the 3 ohm coil and related to a zero of 1 mV/dyne/cm^2 is -131 db, a figure which is low but adequate.

II MODIFICATIONS IN TECHNIQUE OF TESTING RIBBON MICROPHONES

General

In view of probable developments in ribbon microphone design, the possibility was considered of carrying out routine tests on such microphones using a motional impedance bridge in conjunction with a level recorder to obtain frequency response curves. To facilitate tests of this kind, the experimental technique described in the first report was slightly modified as described below.

Bridge Circuit

As a result of experience in operating the motional impedance bridge, a change was made in the method of eliminating residual reactance unbalance. A slight degree of unbalance of this kind can be approximately compensated over the frequency range concerned by adjustment of the condenser C2 (Report M.009 Fig. 1) connected across R1 or R2. Where a greater degree of reactance unbalance is present, however, it is necessary to provide variable condensers across both R1 and R2 if the static balance is to hold good over the entire frequency range of interest. In theory, the bridge then requires to be adjusted with the tone source set

alternately at two different frequencies to secure balance over the entire band. However, once an initial balance has been obtained for the fundamental frequency applied, any harmonics present in the tone source output become audible at the output of the bridge; and the final adjustment can usually be effected by balancing alternately on fundamental and on harmonics until both are reduced to a minimum.

Clamping of Ribbon

A change was also made in the method of holding the ribbon stationary during adjustment of the static balance. The method described in the first report requires a clamping block which fits accurately between the poles of the microphone magnet and which can be readily withdrawn without damaging the ribbon. There is no difficulty in meeting this requirement in the case of a laboratory standard with pole pieces of the form used in the AXBT microphone but practical difficulties may arise if the method is applied to microphones having a different form of magnet system, the dimensions of which will be subject to production variations. Moreover, effective mechanical restraint can only be obtained if the ribbon corrugations can be flattened against the clamping block without permanent deformation and not all forms of ribbon lend themselves to this treatment.

An alternative method of preventing ribbon motion was therefore adopted the principle of which is to immerse the ribbon in a medium of high acoustic impedance. For reasons of efficiency, microphone ribbons are so designed that their mechanical impedance is of the same order as that of the load imposed on them by the surrounding air. Any of the common liquids has a density of the order of 1000 times that of air and the substitution of such a liquid for air will therefore reduce the ribbon motion to negligible proportions. It is, of course, essential that no trace of the liquid should remain on the ribbon when the motional impedance is being measured and the substance used must, therefore, be reasonably volatile. Ethyl ether was first tried, but the rapid evaporation from the exposed surface of the liquid lowered the temperature of the ribbon sufficiently to upset the static resistance balance. Eventually a mixture of benzene and carbon tetrachloride was

adopted; this liquid does not evaporate fast enough to cause serious temperature changes but leaves the ribbon dry in three to five minutes.

To avoid disturbing the low impedance bridge connections to the ribbon, the microphone under test is fixed, and the bath containing the benzene-carbon tetrachloride mixture is raised into position and withdrawn as required. To prevent damage to the ribbon from excessive deflection when the bath is being moved, the microphone is mounted vertically.

With these modifications in technique the tracing of a low-frequency response curve becomes a simple operation taking some 10 minutes to complete. It is not necessary to preserve silence during the process and measurements have been made in a room in which a loudspeaker was reproducing programme at normal listening level. The method has been used in development work requiring over 100 curves and there is no reasnn why a similar procedure should not be adopted whenever a routine check of low-frequency response is necessary.

Conclusion

An experimental diaphragm type velocity microphone standard has been constructed and calibrated by notional impedance measurements. The useful frequency range extends up to 200 c/s and the sensitivity, while low, is adequate for laboratory measurements down to 40 c/s.

The experimental technique for calibrating ribbon velocity microphones has been improved. The method has been used extensively in development work, involving large numbers of frequency response curves in the region below 1000 c/s and could be applied to routine testing.

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CALIBRATION OF VELOCITY MICROPHONES BY MEASUREMENT OF MOTIONAL IMPEDANCE.

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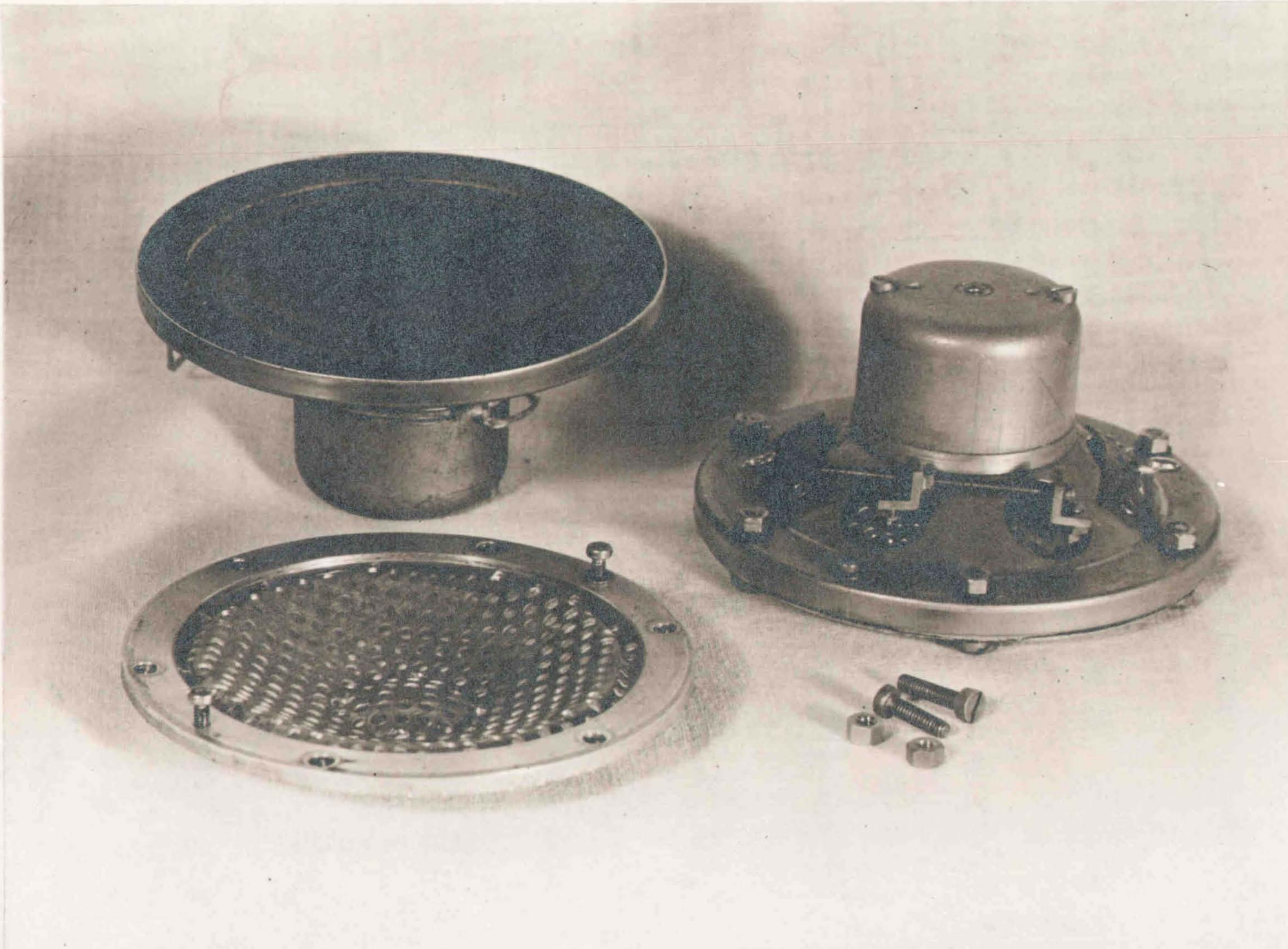

FIG. I

MOVING COIL UNIT MODIFIED FOR MOTIONAL IMPEDANCE CALIBRATION

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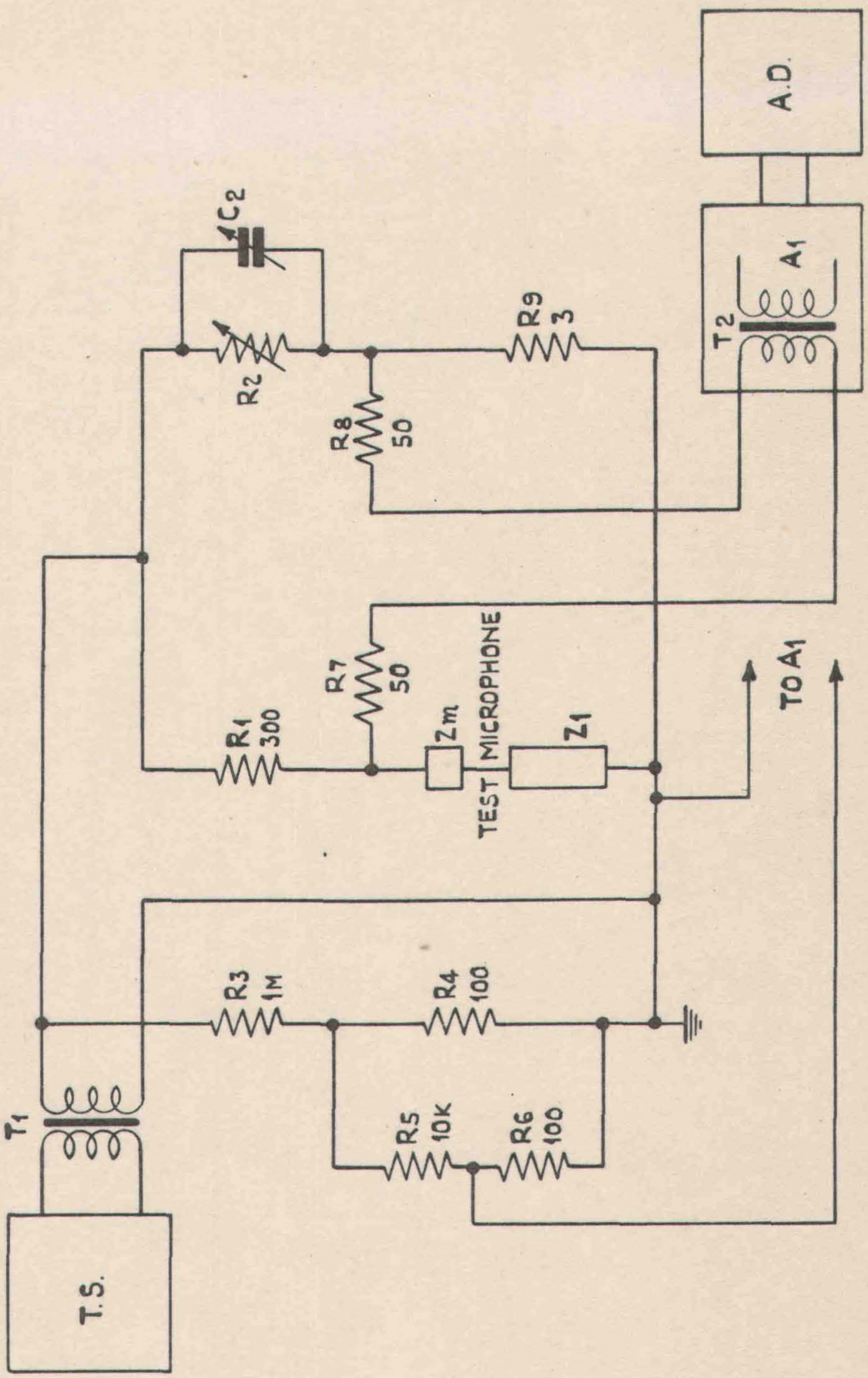

FIG. 2

MOTIONAL IMPEDANCE BRIDGE CIRCUIT.

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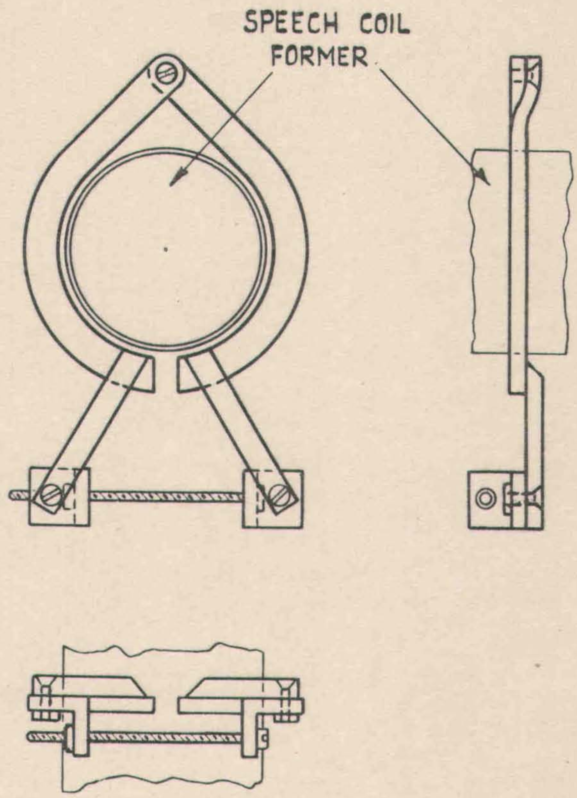

SPEECH COIL CLAMP

FIG.3

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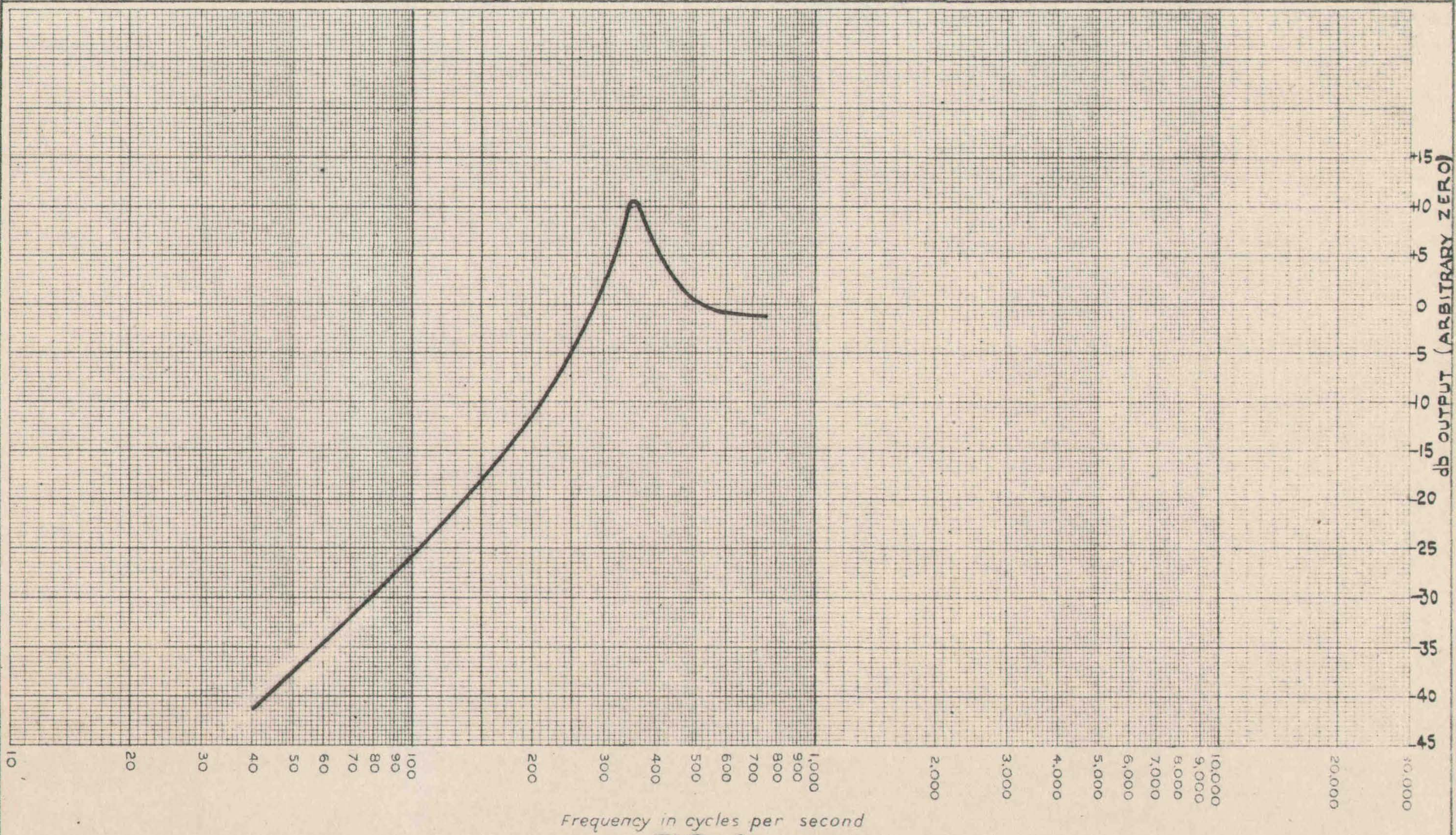

FIG.4

OUTPUT OF VITAVOX UNIT TYPE 1084 USED AS VELOCITY MICROPHONE.

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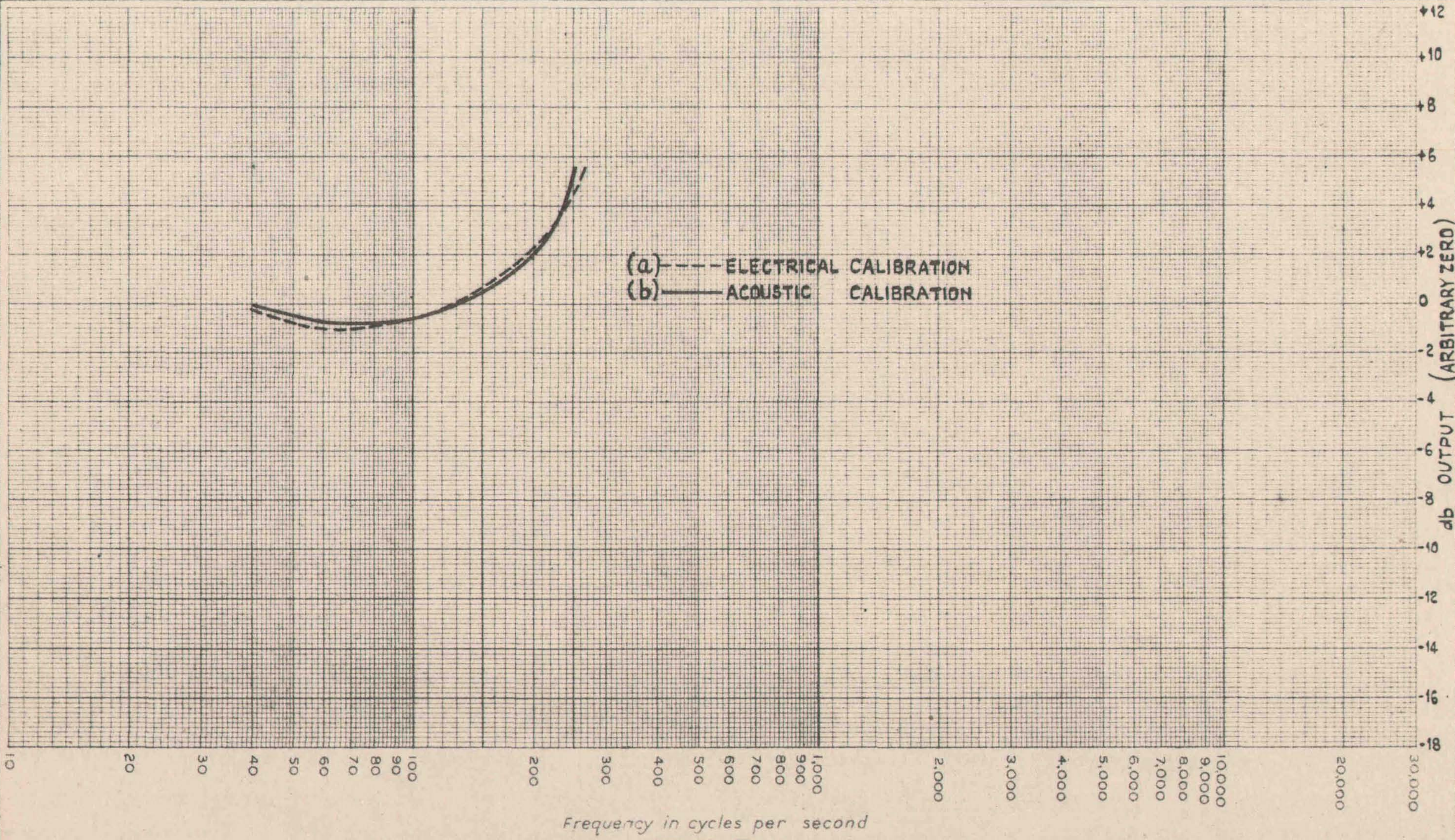

FIG. 5

OUTPUT OF VITAVOX UNIT TYPE 1084 USED AS VELOCITY MICROPHONE PLUS 12db/OCTAVE SLOPE.

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